HEDGEROWS AS FORM OF AGROFORESTRY TO SEQUESTER AND STORE CARBON IN AGRICULTURAL LANDSCAPES: A REVIEW

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Abstract

Hedgerows are an intrinsic part of the agricultural landscape in Europe. As an anthropogenic feature it is difficult to ascertain the carbon storage potential. We performed a systematic literature review on the potential of hedgerows to take in and store carbon. Results show two emerging trends to consider. Aboveground biomass storage estimates range from 5 t C ha^{-1} to 131 t C ha^{-1}. Maintenance of hedges is ascribed as leading to differences in estimation as a result of continually trimming and shaping. .There has also been a decline in hedge length across Europe over the past decades leading to losses of biomass. Soil organic carbon stocks below hedgerows range from 5 t C ha^{-1} to 360 t C ha^{-1}. Hedgerows can thicken soil horizons, prevent erosion and interact with soil water and nutrients. The hedgerow ecosystem is highly localised with differing levels of material input and decomposition. Therefore it is needed to ascertain carbon assimilation and storage to improve estimates for national GHG inventories.

Keywords: hedgerow carbon; hedge carbon; carbon storage; landscape carbon; soil carbon

Introduction

Hedgerows, as an agroforestry system, combine trees/shrubs and agriculture on the same land. This epitomises a land sharing approach to reap multiple benefits; traditionally multiple food or food plus wood crops. In terms of environmental benefits hedgerows present an option for climate mitigation, absorbing and storing carbon on the same land while still producing food or other agricultural outputs.

Hedgerows are lines of woody material on agricultural land used primarily for the division of land parcels. A distinction must be made between the word 'hedgerow' (which incorporates all biomass material and the associated land, banks, ditches and soils) and the word 'hedge' (which is simply the vegetation associated with hedgerows) (Black et al. 2014; Barr and Gillespie 2000).They must be >20m long. They can be viewed similarly to shelter belts or alley cropping, lines of trees with crops growing in-between. Hedges form a network across the landscape and account for large amounts of land, e.g. approx. 3% land in Northern Ireland is under hedge (McCann 2007). Hedgerows have been extensively studied for their ecological benefit however they have rarely been studied for carbon sequestration and storage potential. In the UK landscape scale models of carbon sequestration fail to incorporate hedgerows into GHG inventories, missing a potentially large sink for atmospheric CO_2 (Moxley et al. 2014).

Hedges are anthropogenic in nature and as such must be continually trimmed, shaped and maintained making measurement difficult. Aboveground storage of carbon is greatly influenced by species composition and position in the landscape. Management is also a concern, incorporation of large machinery into the farming landscape in the 1960's lead to declines in hedge length in England and Wales of ~43% (Carey 2008). This has been replicated in other European countries. It has been estimated that the EU-27 can incorporate 17 million km of hedgerow (Aertsens et al. 2013).

Materials and methods

A systematic literature review relating to information on hedge carbon storage and sequestration rates was utilised to search for and gather publications for review. This method was chosen as the most appropriate approach to minimize bias towards particular publication journals, authors or study type and to ensure searches captured as many relevant publications as possible. Information was extracted and trends identified to gain an understanding of current work. No restrictions were placed on geographic location or time of publication. A further search of grey literature was conducted including information from government reports, conference proceedings and contact with authors.These formed the basis of the search terms to be utilized in gathering publications for assessment. General themes from review are presented here.

Results

Two main areas for consideration emerged from literature review, aboveground and belowground.

Aboveground

Carbon storage is not easily quantifiable with variations across location and species composition. Our search estimates carbon storage in the range 5 t C ha^{-1} to 131 t C ha^{-1} and carbon input rates from 0.37 t C ha^{-1} yr^{-1} to 45.78 t C ha^{-1} yr^{-1}. Discrepancies arise due to maintenance. As an anthropogenic feature of the landscape hedges are continually trimmed and shaped. Maintenance consists of either trimming, using a mechanical flail, laying, where the hedge is cut back shaped and allowed to regrow, or coppiced, where the majority of aboveground biomass is removed and regrowth occurs from the little material left. Maintenance has impacts on hedge regrowth, affecting both storage and input rates. In a coppiced system hedge biomass fell to 21% (Blackthorn) and 27% (Hawthorn) of previous storage capacity (Crossland 2015). Regrowth potentials also differ, Hazel (*Corylus avellana*) showed the best re-growth after one year at >200cm shoot growth, Hawthorn (*Crataegus monogyna*) approx. 125cm and Blackthorn (*Prunus spinosa*) showed the least re-growth at approx. 40cm (Westaway et al. 2016). Carbon storage is highly dependent on the use of hedge biomass. Trimmed material that is subsequently burnt returns CO_2 to the atmosphere, thus limiting potential sequestration.

Declining hedge length leads to declines in biomass and thus carbon storage. In Britain between the 1950's and 2000's there was a decline of approx. 43% in hedge length. This pattern is repeated in other countries such as Germany (Poschlod and Braun-Reichert 2017). The EU-27 could potentially introduce 17.8 million km of hedge incorporating 18 million tonnes C annually (at a rate of 0.366 t CO_2-eq ha^{-1} yr^{-1}) (Aertsens et al. 2013). Reasons for hedge loss are largely social, with removal dependent on the surrounding land use. A trade-off exists, where hedges provide ecosystem services, such as carbon storage; they can be seen as an interruption to production limiting access of large machinery and can be expensive to establish. These declines in hedge length can have negative impacts on landscapes ability to store carbon.

Belowground

Soil plays an important role in the functioning of agroecosystems, including sequestration of carbon. A paucity of data exists on the effects hedgerows have on soil organic carbon (SOC) stocks. We suggest SOC stocks under hedge range from 5t C ha^{-1} to 360t C ha^{-1}. Carbon stocks are higher under a hedge than the surrounding cropped land area. Hedgerow soils are usually undisturbed, where humification processes show similar patterns to those in a forested soil (Sitzia et al. 2014). Hedgerows increased carbon stocks by up to 114% compared to treeless areas (Van Vooren et al. 2017). SOC contents were higher adjacent to a hedge structure, dissipating with distance (median value 16.6 kg C m^{-2} hedge side vs 13.3 kg C m^{-2} landscape value) and depth in a hedged landscape (Follain et al. 2007). SOC contents are also affected at depth under hedgerow. Mean carbon content increased from the 0-10cm layer and declined again from the 10-30cm layer (Follain et al. 2007) SOC stocks in a silvoarable system were also higher in the upper layers however the situation was reversed for lower layers

(>150cm) (Upson and Burgess 2013). Fractionation of soil under silvopastroral systems showed a significant increase in C pools at the micro-aggregate, silt and clay sizes, leading in the long term to increases in recalcitrant fractions (Fornara et al. 2017). Hedgerow influence can extend beyond the reach of the branches, with a zone showing higher concentrations of major ions, dissolved oxygen, a deeper water table and higher hydraulic conductivity.

There is a pronounced barrier effect when hedgerows are placed across a sloping plane. Up to 60m upslope from a hedgerow in such a situation soil 'A' horizon was thicker and more developed with significantly higher levels of carbon compared to the downslope (Walter et al. 2003). This thickening was observed for the higher levels of soil only and not at lower levels. This prevention of erosion was not observed by Chaowen et al. (2007) however who observed soil particles eroding laterally. Their study was conducted with hedge strips, highlighting the importance of the interconnectedness of the hedgerow network in the landscape. Thickening was found to remain in the landscape decades after removal of hedgerow (Follain et al. 2009) Hedgerows therefore also display a significant temporal effect.

Previously researchers have used estimates from agroforestry to model sequestration rates. Using information from short rotation Poplar, (Taylor et al. 2010) estimated that hedges would sequester enough carbon to offset 5% of on farm emissions. Hedges have been incorporated into process based models such as RothC and Landsoil (Lacoste et al. 2014). Accurate information about specific hedge species should be gathered and used. Allometry for example has been applied to many forestry and agroforestry systems. Such destructive sampling would provide the information necessary to complement models and provide more accurate assessments. To our knowledge they have yet to be applied to the hedgerow system.

Conclusions

Hedges are lines of woody material, however as an anthropogenic feature of the landscape it is difficult to ascertain the carbon storage potential. Estimates range from 5 to 131 t C ha^{-1}. Belowground hedgerow soils store between 5 and 360 t C ha^{-1}. Discrepancies arise due to differing management and surrounding land use. They exhibit influence on nutrient levels and help in prevention of erosion and thickening of soils, increasing carbon stocks relative to adjacent cropped land. Potential sequestration relating to hedges is highly dependent on the use of biomass material. More work is needed to ascertain carbon assimilation and storage to improve estimates from modelled situations having impacts for national GHG inventories.

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